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RING FOCUS ANTENNA FEED

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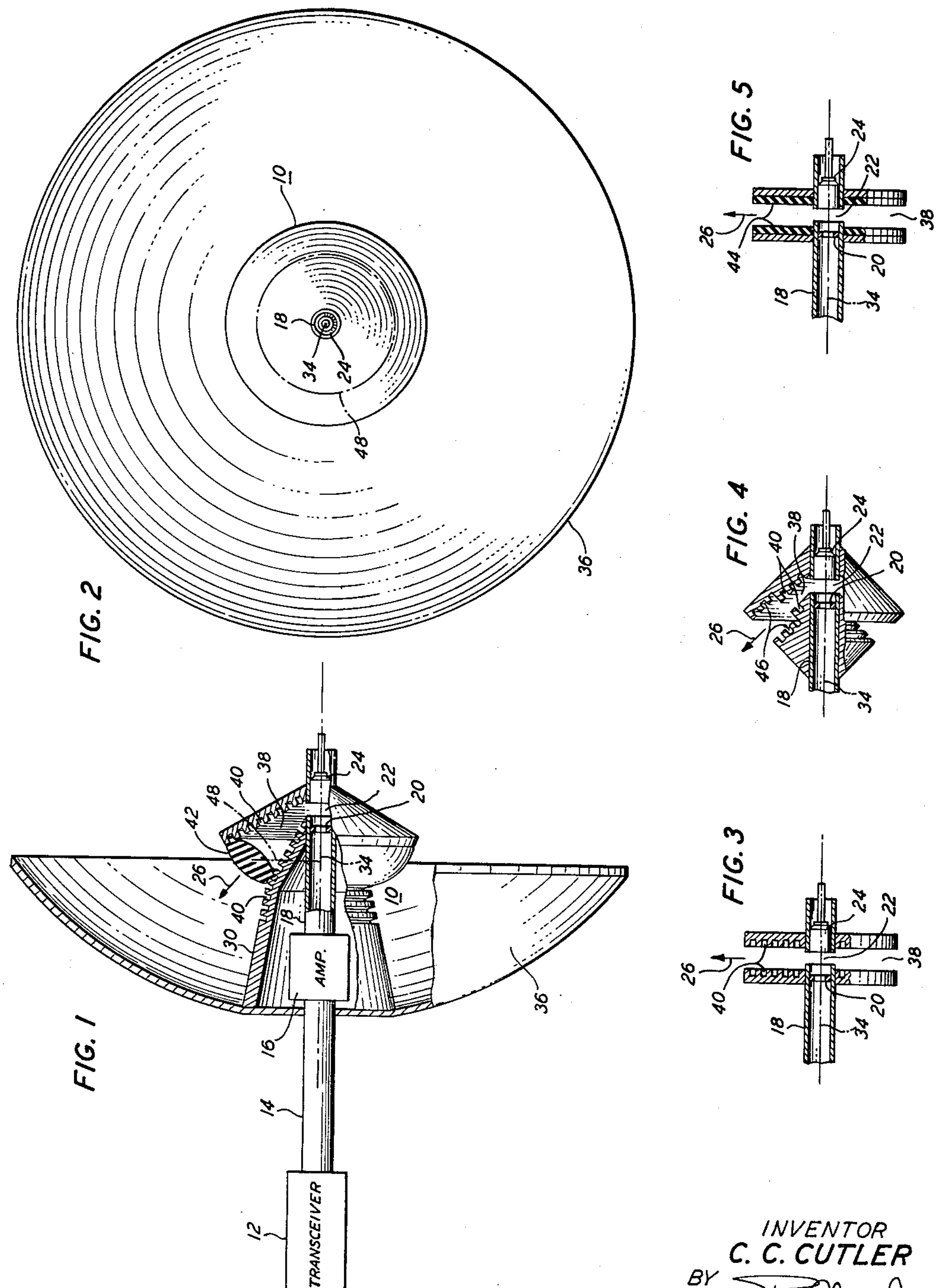

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RING FOCUS ANTENNA FEED

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This invention relates to antennas and, more particularly, to a low noise temperature paraboloidal antenna.

Contemplation of a worldwide space satellite communication complex has provoked renewed interest toward the reduction of the noise encountered in radio receivers. Very little thermal noise attaches to radio signals during transmission in space communications because of the cold medium that outer space presents to propagating signals. Thus, conventional receiver components are outdated and inadequate for use in space communications as they result from a design goal which requires only that the noise contributed by the receiver shall be comparable, and preferably, no greater than that attaching to received signals transmitted in the long established manner, that is, essentially within the atmosphere which is replete with thermal energy. Further, developments of such low noise-generating components as the maser amplifier, have focused attention upon the antenna of receiver systems as the prime contributor to the overall system noise.

The high directivity of paraboloidal antennas and their advantages in cost, size and weight as compared with other directional antennas make such antennas attractive for use in space communication. A great deal of thermal noise energy, however, reaches the feeding element of such antennas directly from the vicinity of the periphery of the paraboloidal reflector without reflection from the reflector. This "spillover," as it is commonly called, represents most of the noise energy contributed to the receiver system by the antenna. In space communications spillover is all the more detrimental as it accounts for an inordinate proportion of the total noise energy picked up by the antenna.

It is, therefore, the object of the present invention to improve the noise characteristics of antenna systems and, more particularly, to reduce spillover in paraboloidal antennas while maintaining a reasonable antenna gain.

In accordance with the above object, a ring focus paraboloidal reflector, as described in my Patent No. 2,482,158 issued September 20, 1949, is illuminated by or focuses upon a feed located in the vicinity of the reflector ring focus. The feed is connected by a waveguide to transmitting and/or receiving equipment situated behind the reflecting surface of the paraboloid. A radial transmission line, forming part of the feed, carries energy between the waveguide and the ring focus with annular uniformity of phase, amplitude and polarization.

More specifically, a gap, the width of which is sufficient to couple all the currents in the waveguide wall, whether longitudinal, transverse or oblique, equally to and from the radial transmission line is cut in the walls of the waveguide. This effects signal coupling with annular uniformity of intensity. Further, a piston strategically located with respect to the gap terminates the waveguide so that the resultant signal (the combination of the reflected signal and the directly coupled signal) coupled between the waveguide and the radial transmission line occurs in time phase circumferentially, i.e., with annular uniformity of phase. To complete the impedance match of the waveguide to the feed, an iris is provided inside the waveguide in the proximity of the gap and between the previously mentioned equipment and the gap.

Annular quarter-wavelength deep corrugations cut transversely in the walls of the radial transmission line

afford a surface presenting uniform annular characteristics to the signal carried by the radial transmission line independent of the local polarization in any particular radial direction. Hence, the feed accommodates and radiates or intercepts a signal wave front exhibiting uniform annular phase, intensity, and polarization and a cosinusoidal intensity distribution across the aperture of the feed.

By varying the angle formed by the direction of propagation of the radial transmission line with the axis, the peak (of the cosine) intensity may be directed toward any portion of the reflector, depending upon the size of the reflector, which provides the most advantageous compromise between minimum spillover and maximum antenna gain under the particular circumstances.

Alternatively, if a uniform intensity distribution across the aperture of the feed is desired a layer or coating of dielectric may replace the corrugations or the radial transmission line may be terminated in a "box" horn with similar annular uniformity of characteristics resulting.

According to another feature of the invention, a pedestal having a base substantially equal in diameter to the ring focus is mounted upon the reflector to furnish a housing for either a first stage of amplification for a receiver or a last stage of amplification for a transmitter. The pedestal also constitutes one wall of the radial transmission line, and isolates opposite sides of the reflector from one another.

The above and other features of the invention will be considered in detail in the following specification taken in conjunction with the drawings in which:

FIG. 1 is a side elevation of an antenna system illustrating the invention;

FIG. 2 is a front elevation of the antenna of FIG. 1;

FIG. 3 is a modification of the feed shown in FIGS. 1 and 2;

FIG. 4 is a feed according to the invention having a box horn aperture; and

FIG. 5 is an embodiment of the invention in which a dielectric coating is substituted for the annular corrugations.

As indicated by FIGS. 1 and 2, the elements comprising the embodiment of the invention disclosed therein are concentric about a common axis 34. For purposes of easy visualization the antenna system of FIGS. 1 and 2 will be explained operating as a transmitting antenna. Of course, it may be employed to receive signals as well in a manner reciprocally related to transmission and it is, in fact, as a receiving antenna that the improved noise characteristics realized by the invention are exploited.

A ring focus paraboloidal reflector 36 is generated by rotating a parabola axis about axis 34 which is parallel to and spaced from the parabola axis. Hence, a ring focus 48, as distinguished from the point focus of conventional paraboloids, is formed. The aperture of reflector 36 in a practical antenna system would probably be at least ten times the diameter of ring focus 48 and, therefore, the diameter of the antenna feed, as they are related in size. For convenience of illustration in FIGS. 1 and 2, however, the ratio of feed diameter to reflector aperture is shown as larger than that given above. Reference is made to Patent No. 2,482,158, previously mentioned, for further elaboration upon ring focus paraboloidal reflectors.

Feed 10 for illuminating reflector 36 is coupled to a transceiver 12 through a circular waveguide 14 which is, in turn, connected to an amplifier 16 which would constitute the last stages of a transmitter (or the first or input stages of a receiver). It is a feature of a ring focus paraboloidal reflector that it has a nonreflecting surface at its center. It is this feature which makes it practicable to place transmitter components such as amplifier 16 so close to feed 10. The signal, amplified for transmission, is launched in a circular waveguide 18 in the TE_{11} mode.

It is desired to radiate from feed 10 a signal wave front having annular uniformity of amplitude, phase, and polarization. What is meant by uniform polarization herein is that the direction of polarization is substantially the same all the way around the aperture or mouth of feed 10. To this end, the currents induced in the walls of waveguide 18 by the propagating signal are broken by an annular gap 22 extending completely around waveguide 18 and are coupled therefrom into a radial transmission line 38. In order to couple the transverse, longitudinal, and oblique currents all equally, i.e., to couple with annular uniformity of signal intensity, the choice of the width of gap 22 is strategic. For if gap 22 is too narrow coupling in favor of longitudinal currents occurs and if it is too wide coupling in favor of transverse currents occurs. The portion of the signal which evades direct coupling to radial transmission line 38 continues to a point shortly beyond gap 22 where a piston 24 terminates waveguide 18. The signal is reflected from piston 24 and returned to gap 22 where it also is coupled to radial transmission line 38. The directly coupled currents are not in time phase around the circumference of the walls of waveguide 18. For example, the transverse currents are 90 degrees out of phase with the longitudinal currents. So in order to have the resultant coupled signal be in phase agreement all around the circumference of gap 22, i.e., exhibit annular uniformity of phase, piston 24 must be adjusted in position to cause the reflected currents to combine with the directly coupled currents in the proper proportion. The adjustment of piston 24 to fulfill this function is an empirical one, as is the width of gap 22, and the position of an iris 20 placed in waveguide 18 to match it, impedance-wise, to the rest of feed 10.

So that radial transmission line 38 carries the signal radiated from feed 10 with annular uniformity of phase, amplitude, and polarization, closely spaced, annular quarter-wavelength deep corrugations 40 are cut in the walls of radial transmission line 38. Radial transmission line 38 must have its walls separated by at least a distance of one-half the wavelength of the signal it is to accommodate in order to propagate such a signal. Then the flow of longitudinal currents in the walls of radial transmission line 38 is inhibited by the corrugations, thus presenting the same surface characteristics to both the electric and magnetic fields. The surface field intensity, therefore, is not affected by local polarization, and a radiating mode having the desired uniformity of phase, intensity, and polarization can exist in radial transmission line 38.

A pedestal 30 having its base substantially equal to the vertex circle of reflector 36 is mounted on reflector 36. Pedestal 30 provides a housing for amplifier 16, so that waveguide 18 may be extremely short, reducing noise accumulated from that source, and also provides one wall of transmission line 38. Pedestal 30 prevents energy emanating from feed 10 from crossing axis 34 and impinging upon the opposite side of reflector 36 and supports feed 10 thus obviating complex feed supports which otherwise would have to be located in the path of the antenna beam. All this may be accomplished with no increase in beam shadow over that formed by feed 10 because the diameter of pedestal 30 is substantially coincident or less than that of ring focus 48 of reflector 36. Since feed 10 is severed into two sections by annular gap 22, an annular dielectric lens 42, forming a window across the aperture of radial transmission line 38, serves to connect and support the two sections of feed 10. In addition, lens 42 may be employed as a trimming adjustment on the annular uniformity of the phase of the signal radiated from feed 10.

The wave front emanating from feed 10 exhibits annular uniformity of polarization, phase and intensity and further, a cosinusoidal intensity distribution across the aperture or mouth of feed 10. The signal radiated from feed 10 onto reflector 36, considered in planes passing through axis 34, is a maximum in the direction of propagation of radial transmission line 38 and falls off to nulls at approximately 45 degrees on either side of that direction of propagation.

In FIG. 1, the direction of propagation of radial transmission line 38 forms an angle of 45 degrees with axis 34, and reflector 36 has its ring focus 48 in the plane of the reflector aperture. Consequently, the peak intensity of the signal emanating from feed 10, signified by arrow 26 (FIG. 1), is directed so that the signal nulls impinge upon reflector 36 near the aperture edge and the base of pedestal 30. Hence, very little energy is wasted as spillover (which in a receiving antenna means little thermal noise is intercepted) or in the form of radiation which falls upon pedestal 30, while at the same time annular uniformity of phase, intensity, and polarization of the signal radiating from feed 10 insures good illumination of reflector 36.

It should be noted that feed 10 carries all linearly polarized signals, regardless of orientation, e.g., vertically or horizontally polarized, with anular uniformity of phase, intensity, and polarization and cosinusoidal intensity distribution in planes including axis 34. Consequently, circularly polarized signals, which find extensive application in space communications, receive the same treatment when applied to feed 10, as they may be thought of as two linearly polarized signals with polarizations rotated in space by 90 degrees with respect to one another and differing in phase by 90 degrees.

FIG. 3 illustrates a radial transmission line 38 the direction of propagation of which forms an angle of 90 degrees with axis 34 of an antenna system like FIG. 1. This feed would find application with a deeper paraboloidal reflector than the one shown in FIG. 1. It becomes evident that the angle made by the direction of propagation of radial transmission line 38 with axis 34 controls the direction of radiation of signal energy from the feed and that this angle may be varied to suit the depth of the reflector and other needs of the immediate situation.

FIG. 4 ilustrates another embodiment of the invention in which the aperture of radial transmission line 38 forms a "box" horn 46. The application of a box horn aperture provides a uniform intensity distribution across the aperture of the horn. This is discussed more fully in my monograph entitled "Parabolic-Antenna Design for Microwaves" published in the Proceeding of the I.R.E. November 1947, on pages 1284 through 1294. Annular uniformity of phase, intensity and polarization are again maintained by corrugations 40 cut in the wall of radial transmission line 38.

As an alternative arrangement to that of FIG. 4, the walls of radial transmission line 38 in FIG. 5 are coated with a dielectrical material 44 rather than corrugations 40 shown in FIGS. 1, 3 and 4. This likewise presents identical surface characteristics to both the electric and magnetic field carried in radial transmission line 38, but develops a uniform intensity distribution across the aperture of the feed.

What is claimed is:

1. In an antenna system, a reflector and a feed element for radiating and intercepting electromagnetic signals to and from said reflector comprising a circular waveguide centered about an axis, a radial transmission line centered about and extending completely around said axis, an annular gap in the wall of said waveguide, an iris located in said waveguide and an adjustable piston terminating said waveguide, said iris and said piston being located with respect to said gap so as to couple said signal with annular uniformity between said radial trans-

mission line and said waveguide, said radial transmission line having walls separated a distance of at least one-half the wavelength of said signal, and said walls having annular quarter-wavelength deep corrugations centered about said axis.

2. In combination, a ring focus paraboloidal reflector having a focal circle included in a plane perpendicular to and centered on the axis of said reflector, a transceiver located behind the radiating surface of said reflector, and an antenna feed comprising a circular waveguide centered about said axis, means for extending said waveguide through said reflector to connect with said transceiver, an annular gap cut in the wall of said waveguide at a point near said focal circle, a radial transmission line connected across said gap and extending completely around said waveguide, said transmission line having walls separated by a distance of at least one-half the wavelength of the signal applied to said feed, said walls having annular quarter-wavelength deep corrugations centered about said axis, and means for coupling said signal between said waveguide and said radial transmission line with annular uniformity of intensity, phase and polarization.

3. In combination, a ring focus paraboloidal reflector having a focal circle included in a plane perpendicular to and centered upon the axis of said reflector, a pedestal having a base diameter substantially equal to or less than said ring focus diameter mounted upon said reflector at the vertex of said reflector, remote electronic equipment, said equipment being housed inside said pedestal, and an antenna feed comprising a longitudinal transmission path having at least one metallic conductor centered about said axis, means for connecting said transmission path to said equipment, a radial transmission line located near said focal circle, the surface of said pedestal constituting one wall of said radial transmission line, and coupling means between said radial transmission line and said transmission path.

4. In combination, a ring focus paraboloidal reflector having a focal circle included in a plane perpendicular to and centered on the axis of said reflector, the edge of said

reflector also being included in the plane of said focal circuit, terminal equipment located behind the radiating surface of said reflector, and an antenna feed comprising a circular waveguide centered about said axis, means for extending said waveguide through said reflector to connect with said terminal equipment, an annular gap in the wall of said waveguide at a point near said focal circle, a radial transmission line connected across said gap and extending completely around said axis, said radial transmission line forming an angle of approximately 45 degrees with said axis, said transmission line having walls separated by a distance of at least one-half the wavelength of the signal applied to said feed, said walls having annular quarter-wavelength deep corrugations centered about said axis, and means for uniformly coupling said signal between said waveguide and said radial transmission line.

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